Semantics of Caching with SPOCA - A Stateless, Proportional, Optimally-Consistent Addressing Algorithm

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Outline

- Introduction
- **Problem Definition**
- SPOCA and Requirements
- Evaluations
- Conclusion
The Problem

- The front-end server disks are a secondary bottleneck.
- Eliminating redundant caching of content also reduces the load on the storage farm.
- An intelligent request-routing policy can produce far more caching efficiency than even a perfect cache promotion policy that must labor under random request routing.
- The cache promotion algorithm not enough.
Problems from Geographic Distribution
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Requirements

- Merge different delivery pools and manage the diverse requirements in an adaptive way.
- Minimize caching disruptions when front-end server leaves or enters the pool - re-address as few files as possible to different servers.
- Proportional distribution of files among servers does not necessarily result in a proportional distribution of requests (Power Law).
SPOCA and Zebra

- Used in production in a global scenario for web-scale load.
- Shows real world improvements over the simple off-the-shelf solution.
- Implements load balancing, fault tolerance, popular content handling, and efficient cache utilization with a single simple mechanism.
Traditional Approach
Zebra Algorithm

- Handles the geographic component of request routing and content caching
- Based on content popularity, Zebra decides when requests should be routed to content’s home locale and when the content should be cached in the nearest locale
- We use bloom filters to determine popularity.
Tracking popularity

add(vid1) → Bloom Filter
Checking Popularity

contains(vid1) → Bloom Filter
What’s the problem here?

- Everything will become popular.
- No way to expire content in bloom filter.
- We use a sequence of bloom filters to track popularity.
Bloom Filter Representation

0
• vid1
• vid5

1
• vid8
• vid526

2
• vid2
• vid752
Bloom Filter Representation

0

1
• vid1
• vid5

2
• vid8
• vid526
Bloom Filter Representation

add(vid8)

0
1
• vid1
• vid5
2
• vid8
• vid526
Bloom Filter Representation

- 0: vid8
- 1: vid1, vid5
- 2: vid8, vid526
Bloom Filter Representation

contains(vid3)

0
• vid8

1
• vid1
• vid5

2
• vid8
• vid526
Bloom Filter Representation

contains(vid3)

Unified Filter

vid1, vid5, vid8, vid526

0
• vid8

1
• vid1
• vid5

2
• vid8
• vid526
Key Points

- **Zebra** determines which serving cluster will handle a given request based on geolocality and popularity.

- **SPOCA** determines which front-end server within that cluster will cache and serve the request.
SPOCA Algorithm

- **Goal**: Maximize cache utilization at the front-end servers.
- Simple content to server assignment function based on a sparse hash space.
- Each front-end server is assigned a portion of the hash space according to its capacity.
- The SPOCA routing function uses a hash function to map names to a point in a hash space.
  - Input = the name of the requested content
  - Output = the server that will handle the request.
- Re-hashing happens till the result maps to a valid hash space.
SPOCA hash map example
Failure Handling

H(vid1) → Server 1
H(H(vid1))) → Server 2
H(H(vid1)) → Server 3

Storage Farm

Server 4
Elasticity
Popular Content

- SPOCA minimizes the number of servers to maximize the aggregate number of cached objects.

- For popular content we need to route requests to multiple front-end servers.

- We store the hashed address of any requested content for a brief popularity window, 150 seconds in our case.

- When the popularity window expires, the stored hash for each object is discarded.
Popularity Window
Before the Request: {}

Popularity Window
After the Request: 
{(vid1, H(H(vid1))))}
Popularity Window Before the Request:
\{ (vid1, H(H(vid1))) \}

Popularity Window After the Request:
\{ (vid1, H(H(H(vid1)))) \}
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Scaling 5x w/o software improvements

Scaling content 5x with no software improvements

- Filer storage
- Filer streaming

Unique streams per day (millions) vs. Filer storage (terabytes) and Daily filer streaming (terabytes)
Scaling 5x with software improvements

Scaling content 5x with software improvements

- Filer storage
- Filer streaming

Unique streams per day (millions)

Filer storage (terabytes)

Daily file streaming (terabytes)
Memory cache hits
## Cache Hit and Misses*

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<th>2/26</th>
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<th>3/7</th>
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<td>7.2%</td>
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<td>1.8%</td>
<td>0.4%</td>
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<td>Download Cache HIT</td>
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<td>13.5%</td>
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<td>2.5%</td>
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* Download and Flash Pools in S1S data center
Conclusion

- Zebra and SPOCA do not have any hard state to maintain or per object meta-data.
- Eliminates any per object storage overhead or management, simplifying operations.
- Consolidate content serving into a single pool of servers that can handle files from a variety of different workloads.
- Decouple serving and caching layers.
- Cost savings and end user satisfaction are key success metrics.